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14. ABSTRACT
A 3-dimensional, time -dependent, multi -species (O+, H+, Os, Hs, electrons) model of the ion and neutral polar winds was used to simulate the dynamics du ring the May 4, 1998 geomagnetic storm. The stormtime simulation was driven by realistic plasma convection and particle precipitation patterns, which pulsated with an approximately 1 -hour time period. This pulsating stormtime energy input to the ionosphere resulted in pulsating ion and neutral polar winds, with the 1 -hour period. The magnitude of the vertical ion and neutral fluxes were correlated with the size of the auroral oval and associated plasma convection pattern. When the oval was expanded, the vertical fluxes tended to be a maximum, and when the oval was contracted the vertical fluxes tended to be a minimum. The largest vertical fluxes were located over the areas where th e electron precipitation was the strongest. In general, the vertical fluxes at the top o f the ionosphere (1500 km) for O+, H+, and Os exhibited a significant amount of spatial structure, with the intensity of the vertical fluxes and the location of the structure varying marked ly with time. This aspect of the storm simulation supports the suggestion by Peterson et al. (2002) that any attempt to include ionospheric outflow in large -scale models of the magnetosphere should take into account the large variations in outflow.

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Annual/Final Report

AFOSR Project: Development of an Ionosphere-Plasmasphere-Polar Wind Model and Studies of Storms and Substorms

Award Number: FA9550-06-1-0217, Larry C. Gardner (Herbert C. Carlson)

The focus of this project was on the development of an ionosphere-plasmasphere-polar wind model to study storms and substorms. Four papers were published in the scientific literature, with the titles and abstracts listed below. The topics studied include polar patch formation and dynamics, including their role in neutral stream particle production. The final paper covers a simulation of the May 4 1998 magnetic storm using realistic inputs to drive the model. By using realistic inputs during storms, there is a more realistic, changing character to the model inputs, thereby showing more of the dynamic, changing nature that should be associated with storm, and substorm simulations. The results of the current studies show that in order to model the near earth environment, realistic inputs are necessary, and with the realistic drivers the model produces a more spatially and temporally varying output. This then shows that to model the magnetosphere-ionosphere interactions, the dynamical nature of the ionspheric flows must be taken into account to accurately portray magnetosphere-ionosphere coupling. More detail on this study is included in the appendix in the form of a powerpoint poster which will be displayed at the Fall AGU meeting.

GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L13101, doi:10.1029/2007GL029316, 2007

Role of neutral atmospheric dynamics in cusp density and ionospheric patch formation

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Abstract

Ionospheric patches are islands of plasma transiting the polar cap, with density at least double the surrounding background plasma. Since their discovery 25 years ago, many mechanisms for their production have been proposed and examined. However all of these mechanisms consider only electric fields and charged particles as candidate mechanisms for patch formation, particularly transient changes in these electrodynamic terms. Here for the first time, we call attention to the role of thermospheric dynamics in Patch formation. We show that the thermospheric response to transient heating events near the cusp must significantly increase exospheric densities over the cusp, and also that a plausible doubling of these densities near and above 400 km altitude leads to a new patch production mechanism. The underlying processes must drive a solar cycle variation of how many hours UT experience strong polar patches and scintillation. These processes must be added to present thinking and modeling.

Received 12 January 2007; accepted 23 May 2007; published 4 July 2007.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, A11304, doi:10.1029/2007JA012384, 2007

Case for a new process, not mechanism, for cusp irregularity production

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Abstract

Two plasma instability mechanisms are currently thought to dominate formation of plasma irregularities in the *F* region high-latitude and polar ionosphere: the gradient-drift driven instability and velocity-shear driven instability. The former mechanism is accepted as accounting for structuring plasma in polar cap patches and the latter for structuring plasma in polar cap Sun-aligned arcs. Recent work has established a dominant patch formation process, involving magnetic reconnection driving strong plasma shears repeatedly observed in the cusp. Proceeding from this, we present the case for a needed new plasma structuring process (not new mechanism), whereby shear-driven instabilities first rapidly structure the entering plasma, after which gradient drift instabilities build on these large "seed" irregularities. Correct modeling of cusp and early polar cap patch structuring will not be accomplished without allowing for this compound process. This compound process also explains previously unexplained characteristics of cusp and early polar cap patch irregularities.

Received 5 March 2007; accepted 14 August 2007; published 16 November 2007.

Propagating plasma patch and associated neutral stream flows

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Abstract

Plasma patches are regions of enhanced ionization that are created in the dayside cusp or equatorward of the cusp in the sunlit hemisphere during northward interplanetary magnetic field. After formation, and a change to a southward interplanetary magnetic field, they drift across the polar cap with the prevailing convection speed. As a plasma patch propagates, charge exchange reactions occur, which lead to the production of both ion and neutral particles throughout the patch. In the region directly above the patch, an upward jet of H+ and O+ forms. This ion jet, in turn, acts to produce an upward flux of neutral H and O stream particles because of charge exchange reactions between the ion jet and the background neutral atmosphere. A three-dimensional, time-dependent model of the ion and neutral polar winds was used in order to study the evolution of the neutral stream particles that are produced in a 'representative' propagating plasma patch, with the anticipation that the neutral stream particles produced by the ion jet would display a distinct signature. However, the outflow of neutral H atoms above a patch is only slightly visible in the simulation due to a continuous outflow flux of H (_109 cm_2 s_1) across the entire polar cap. On the other hand, the upward flux of neutral O from the patch is more dependent on both the state of the ionosphere and the amount of heating, with increased upward fluxes over areas where the heating is high. Typically, the upward neutral O streams are predominantly located in the pre-midnight auroral oval.

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Pulsating Ion and Neutral Polar Winds

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Abstract

A three-dimensional, time-dependent model of the ion and neutral polar winds was used to study their dynamic evolution during the May 4, 1998 magnetic storm. The simulation tracked the dynamics of five species (O+, H+, Hs, Os, and electrons) and covered a 9-hour period. During the storm, Dst decreased to -210 nT, Ap reached 300, and Kp was elevated. The IMF Bz component was southward at the start of the storm and for several hours thereafter and then turned northward. However, the magnetospheric energy input to the ionosphere exhibited a 1-hour oscillation, with the plasma convection and particle precipitation patterns expanding and contracting in a periodic manner. As a consequence, the ion and neutral polar winds pulsated with an approximate 1-hour period. The H+ and O+ ions displayed cyclic upflows and downflows in the topside ionosphere as well as a highly structured spatial distribution that varied with time. The vertical flux of the neutral Hs atoms was upward at the top of the ionosphere, but the magnitude varied in a cyclic manner in response to the oscillating stormtime energy input. The vertical flux of neutral Os atoms was downward at the top of the ionosphere and varied significantly with the stormtime energy input. For H+, O+, and Hs, the maximum total (integrated) vertical flux during the storm was upward at the top of the ionosphere, with values of 8-9 x 1025 particles/sec for H+, 2-4 x 1026 particles/sec for O+, and 2-3 x 1027 particles/sec for Hs. The corresponding total vertical Os flux was predominately downward, with only localized areas with positive fluxes.

Submitted To JASTP October 2007

APPENDIX

Slide 1

Pulsating Ion and Neutral Polar Winds

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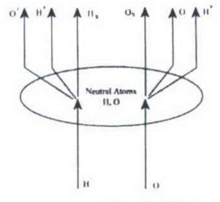
Slide 2

Abstract

A three-dimensional, time-dependent model of the ion and neutral polar winds was used to study their dynamic evolution during the May 4, 1998 magnetic storm. The simulation tracked the dynamics of five species (O^+, H^+, H_s, O_s, and electrons) and covered a 9-hour period. During the storm, D_{st} decreased to -210 nT, Ap reached 300, and Kp was elevated. The IMF B_z component was southward at the start of the storm and for several hours thereafter and then turned northward. However, the magnetospheric energy input to the ionosphere exhibited a 1-hour oscillation, with the plasma convection and particle precipitation patterns expanding and contracting in a periodic manner. As a consequence, the ion and neutral polar winds pulsated with an approximate 1-hour period. The H^+ and O^+ ions displayed cyclic upflows and downflows in the topside ionosphere as well as a highly structured spatial distribution that varied with time. The vertical flux of the neutral H_s atoms was upward at the top of the ionosphere, but the magnitude varied in a cyclic manner in response to the oscillating stormtime energy input. The vertical flux of neutral O_s atoms was downward at the top of the ionosphere and varied significantly with the stormtime energy input. For H^+, O^+, and H_s, the maximum total (integrated) vertical flux during the storm was upward at the top of the ionosphere, with values of 8-9 x 10^{25} particles/sec for H^+, 2-4 x 10^{26} particles/sec for O^+, and 2-3 x 10^{27} particles/sec for H_s. The corresponding total vertical O_s flux was predominately downward, with only localized areas with positive fluxes.

Slide 3

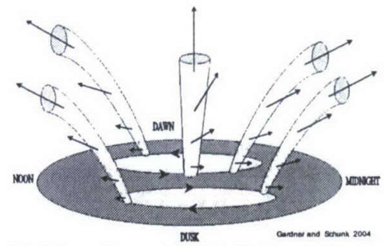
Polar Cap Dynamics



Gardner and Schunk 2004

Charge exchange reactions produce fast moving neutrals from fast moving ions.

Ions move horizontally due to convection electric fields, and vertically due to the ambipolar electric field, and pressure gradients.

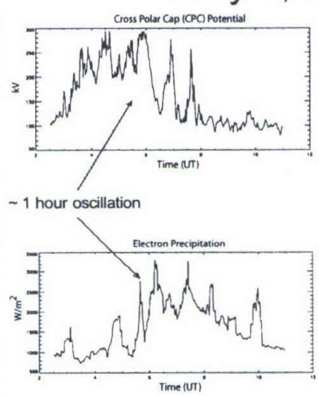


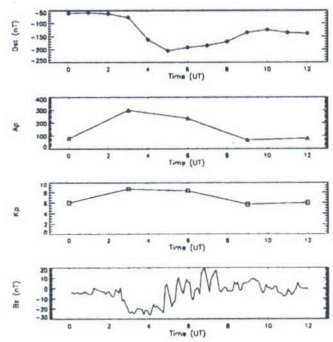
Gardner and Schunk 2004

Neutrals are then produced via charge exchange reactions (arrows)

Slide 4

May 4, 1998 Storm





Storm Parameters

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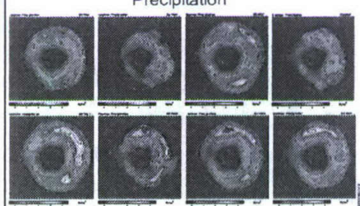
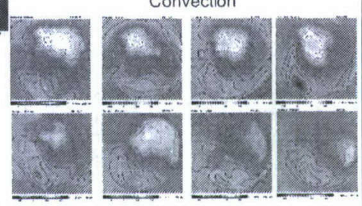
Realistic Model Drivers

Precipitation



Precipitation patterns from AMIE, showing a temporal and spatial oscillation in the energy input to the auroral oval.

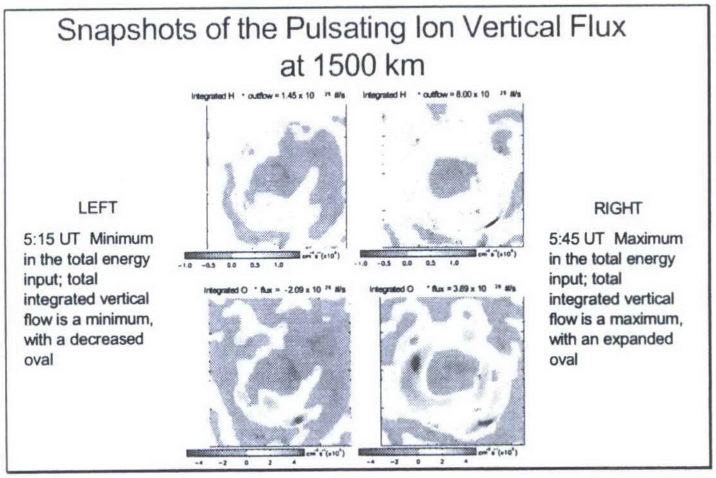
Convection



Convection patterns from AMIE, showing the temporal and spatial changes in the high-latitude potential structure.

AMIE data courtesy of Aaron Ridley (cf. Bekerat et al. 2005)

Slide 6



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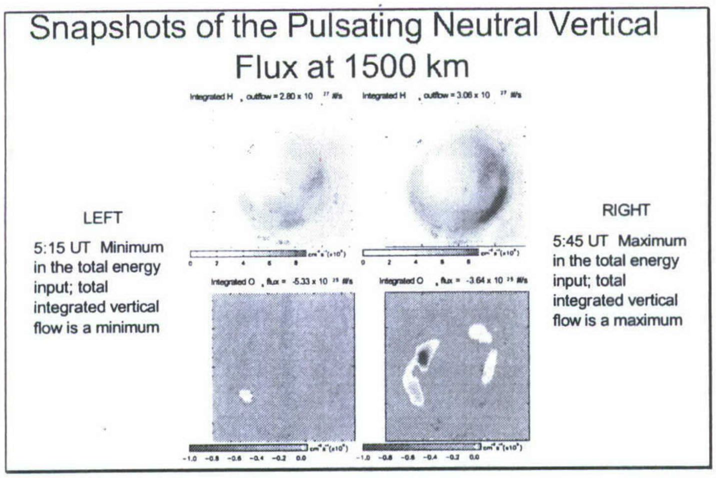

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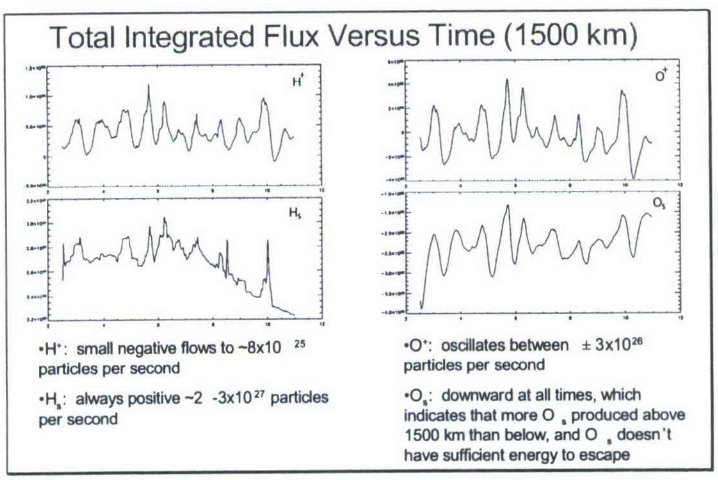

Slide 9

Summary

A 3-dimensional, time-dependent, multi-species (O+, H+, Os, Hs, electrons) model of the ion and neutral polar winds was used to simulate the dynamics during the May 4, 1998 geomagnetic storm. The stormtime simulation was driven by realistic plasma convection and particle precipitation patterns, which pulsated with an approximately 1-hour time period. This pulsating stormtime energy input to the ionosphere resulted in pulsating ion and neutral polar winds, with the 1-hour period. The magnitude of the vertical ion and neutral fluxes were correlated with the size of the auroral oval and associated plasma convection pattern. When the oval was expanded, the vertical fluxes tended to be a maximum, and when the oval was contracted the vertical fluxes tended to be a minimum. The largest vertical fluxes were located over the areas where the electron precipitation was the strongest. In general, the vertical fluxes at the top of the ionosphere (1500 km) for O^+, H^+, and O_s exhibited a significant amount of spatial structure, with the intensity of the vertical fluxes and the location of the structure varying markedly with time. This aspect of the storm simulation supports the suggestion by Peterson et al. (2002) that any attempt to include ionospheric outflow in large-scale models of the magnetosphere should take into account the large variations in outflow.